Monitoring Physical and Cognitive Performance During Sustained Military Operations

Susan Vrijkotte, Msc., Pierre J.L. Valk, MSc.
TNO Defence, Security and Safety
Department of Human Performance
P.O. Box 23
3769 ZG Soesterberg
NETHERLANDS
Tel: +31 346356470 / Fax: +31 346353977

susan.vrijkotte@tno.nl

Bertil J. Veenstra, MSc., Taco Visser, MSc.
Royal Netherlands Army: Training Medicine and Training Physiology
P.O. Box 90004
3509 AA Utrecht
NETHERLANDS

ABSTRACT

Soldiers are exposed to extreme, complex and sustained operations. During operations the limits of human capabilities are easily reached leading to a diminished operational readiness. The status of a soldier is estimated by the commander based on his subjective observations. This commander evaluation can be biased by personal experiences and commanders own physical and mental status. A wrong judgement by a commander in a dangerous and harmful situation may have negative consequences for the soldier. Until recently, no methods were available for the Dutch Army to monitor the physiological and cognitive status of soldiers during (sustained) military operations. In order to develop a tool to predict the operational readiness of soldiers an investigation took place during an Air Mobile Training Course in which physical and cognitive performance was measured. This paper focuses on the cognitive measurements performed during the course. During three of the seven course weeks, which were the physically strenuous weeks, soldiers were tested. Test sessions took place on Monday, Wednesday and Friday morning as well as on Wednesday and Friday afternoon (five measurements per week). Cognition was measured using three tasks. The N-Back (Zero-Back, One-Back and Two-Back), Tower of Hanoi and VigTrack were used to gain insight in soldiers working memory, logical reasoning, vigilance and tracking. The tasks took about 5 minutes each to complete. The results show that cognitive performance remains relatively stable over two of the three weeks. During the second week two significant drops in cognitive performance were found. Soldiers showed quick recovery, regaining normal cognitive performance within the same day. The results of the three cognitive tasks all revealed the same pattern in their results. Working memory, logical reasoning as well as vigilance and tracking were all affected during the weeks measured. During weeks 1 and 3 cognitive performance decreased over the week, whereas the cognitive performance during the second week of the training course showed a different pattern with major drops in performance during that week. During the second week soldiers were exposed to physically as well as high psychologically strains. High psychological strains were absent during the first and third week. In conclusion, cognitive performance is affected when soldiers experience high physical with or without psychological strains. Little time is needed for recovery; previous performance levels are regained fast. It remains to be investigated whether the decrements in performance are the result of the high physical, with or without psychological, load or whether other factors such as lack of sleep, nutrition or liquids play a role.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2009	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Monitoring Physical and Cognitive Performance During Sustained Military Operations	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **TNO Defence, Security and Safety Department of Human Performance P.O. Box 23 3769 ZG Soesterberg NETHERLANDS**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

See also ADA562561. RTO-MP-HFM-181 Human Performance Enhancement for NATO Military Operations (Science, Technology and Ethics) (Amelioration des performances humaines dans les operations militaires de l'OTAN (Science, Technologie et Ethique)). RTO Human Factors and Medicine Panel (HFM) Symposium held in Sofia, Bulgaria, on 5-7 October 2009., The original document contains color images.

14. ABSTRACT

Soldiers are exposed to extreme, complex and sustained operations. During operations the limits of human capabilities are easily reached leading to a diminished operational readiness. The status of a soldier is estimated by the commander based on his subjective observations. This commander evaluation can be biased by personal experiences and commanders own physical and mental status. A wrong judgement by a commander in a dangerous and harmful situation may have negative consequences for the soldier. Until recently, no methods were available for the Dutch Army to monitor the physiological and cognitive status of soldiers during (sustained) military operations. In order to develop a tool to predict the operational readiness of soldiers an investigation took place during an Air Mobile Training Course in which physical and cognitive performance was measured. This paper focuses on the cognitive measurements performed during the course. During three of the seven course weeks, which were the physically strenuous weeks, soldiers were tested. Test sessions took place on Monday, Wednesday and Friday morning as well as on Wednesday and Friday afternoon (five measurements per week). Cognition was measured using three tasks. The N-Back (Zero-Back, One-Back and Two-Back), Tower of Hanoi and VigTrack were used to gain insight in soldiers working memory, logical reasoning, vigilance and tracking. The tasks took about 5 minutes each to complete. The results show that cognitive performance remains relatively stable over two of the three weeks. During the second week two significant drops in cognitive performance were found. Soldiers showed quick recovery, regaining normal cognitive performance within the same day. The results of the three cognitive tasks all revealed the same pattern in their results. Working memory, logical reasoning as well as vigilance and tracking were all affected during the weeks measured. During weeks 1 and 3 cognitive performance decreased over the week, whereas the cognitive performance during the second week of the training course showed a different pattern with major drops in performance during that week. During the second week soldiers were exposed to physically as well as high psychologically strains. High psychological strains were absent during the first and third week. In conclusion, cognitive performance is affected when soldiers experience high physical with or without psychological strains. Little time is needed for recovery; previous performance levels are regained fast. It remains to be investigated whether the decrements in performance are the result of the high physical, with or without psychological, load or whether other factors such as lack of sleep, nutrition or liquids play a role.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**12**	

1.0 INTRODUCTION

In Iraq, Afghanistan and Bosnia soldiers are exposed to extreme, complex and sustained (72 hours continuous performance) operations in urbanized and irregular terrain. During these operations, along with the threat of physical and chemical attack, the mountainous terrain and the changing climatological, these circumstances are considered to be the 'standard' environments in which soldiers have to operate. In addition to the extreme environments, factors such as sleep deprivation [1], operating during the night, and limited calorific intake due to sustained operations, influence the performance of soldiers (Figure 1) [2,3,4]

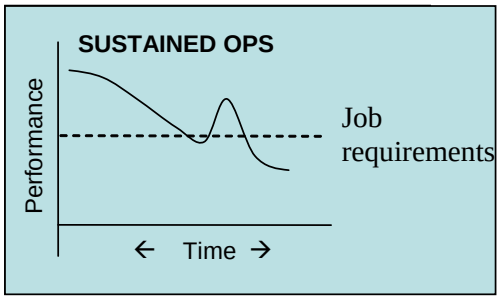

Figure 1: Performance fluctuations of soldiers during sustained operations.

In order to fulfill job requirements, soldiers must be able to achieve a certain level of performance. As long as the soldier's performance level is higher than the job requirements, soldiers will be able to fulfill their duties. When the performance level of a soldier drops below the required job performance level they become susceptible to making mistakes and/or getting injured which leads to an unsafe environment for both the soldier and the platoon. However, under extreme and sustained operations the limits of human capabilities are easily reached leading to an impaired performance. The prevalence of these situations needs to be kept as low as possible. Commanders are responsible for the performance of their men and it is their subjective judgement of soldier's operational readiness that determines the decisions and actions taken. Although personal experiences and a good knowledge of the people they work with provide the commander with a lot of information about the status of a soldier, there is a need for additional tools to support commanders in their decision-making processes; especially in complex, strenuous and stressful situations. Objective measures of cognitive and physical performance, may help the commander find the optimal balance between the job requirements and the operational readiness of their soldiers. This would enhance the sustainability of the soldier and therefore increases his effectiveness.

In training and operational situations the data attained from some simple physiological/psychological monitoring of the soldier in question might be useful in assisting the commander evaluating the soldier's operational status and facilitate his decision making process based on objective measures. The provision of such information may prevent a situation occurring where soldiers are instructed to perform tasks that are beyond their current capabilities. Decisions based on additional physiological/psychological data provides support to the commanders subjective decision and may provide them with the opportunity to better plan operations ensuring that the operational readiness of soldiers is best preserved. The evaluation of the effects of operational deployment on soldier's sustainability may benefit from the data attained via soldier monitoring. Consequently, the most appropriate action/decision, with the least consequences for soldier's operational status, could be chosen for future operations.

Monitoring soldiers is potentially useful during training situations. Monitoring the physiological/ psychological status of a soldier may help prevent injuries, overtraining syndrome and/or drop outs. Soldiers who reach the limits of their capabilities could be identified, separated from the group and given a specific training program in order to regain fitness and prevent injuries. In addition to ensuring that the

minimal level of fitness is identified and attained soldier monitoring would enable trainers to make small specific adjustments in the training programs leading to large benefits; fit soldiers who complete their training course.

The Performance and Health Monitoring program tries to gain insight into several physiological and cognitive processes and their influence on performance. In order to develop a predictive performance tool four processes are required. These processes are:

1) *Evaluating which factors have an effect on soldier's sustainability and determining how each of these factors can be best measured.*
2) *Monitoring/ assessing/ measuring soldier's performance.*
3) *Determining the relationship between factors that influence soldier's operational readiness and actual physical and cognitive performance.*
4) *Predicting the operational readiness and sustainability of soldiers*.

At this stage of the research program the primary focus is to determine how parameters influencing performance can be best assessed during training. The initial study was conducted during the VAKOL (Air Mobile Training Course) education training program.

To enable measurements to be taken in the field, field labs were developed. These field labs made it possible to measure soldiers during their operations whilst minimizing interference with their tasks. Soldiers can be equipped with physiological monitoring systems and cognitive tasks can easily be fitted into the training schedules of the soldiers. It is not always possible to use the most accurate and sensitive measurement devices due to the limiting factors of the field study. Using the outcome of the reviews and taking into account the limitations of performing field studies, we choose to measure the following:

- Climatic: Using the WBGT and weather stations for environmental temperature, rainfall, wind speed, and humidity.
- Physiology: Body mass, percentage body fat, heart rate (ECG), respiration rate, core temperature, skin temperature, accelerometry, and body position.
- Cognition: Working memory, logical reasoning and alertness.
- Subjective ratings: Sleep, perceived exertion, state and traits anxiety, emotions, need for recovery and mental strain.
- Energy consumption: Water and caloric intake. Energy consumption was measured with a device (SenseWear Pro) as well.
- Distance covered: GPS.
- Instructor ratings.

This paper focuses on the effects of sustained operations on cognitive performance. Cognitive performance is affected by the level and the duration of physical strains, level of fitness, age, gender and experience. Physical exercise can influence cognition positively and negatively. The study of Hogervorst [5] showed improvements in cognitive performance speed after strenuous exercise while Fery [6] showed that decision reaction time was affected during an exhausting bout of a progressive workload session. The extent to which cognitive performance is affected during sustained operations, where soldiers have to deal with extreme circumstances, remains unanswered.

Do extreme physical and mental load and sleep deprivation during sustained training settings influence cognitive performance of soldiers? If so, to what extent is cognitive performance affected and how soon can performance be regained? It is hypothesized that the cognitive performance of soldiers decreases over time since the sustained operation places a high demand on the soldiers capabilities.

2.0 METHODS

2.1 Subjects

Soldiers (20 – 43 year old; mean ± sd: 29.1 ± 5.3) who qualified for the Air Mobile Brigade training course took part in this investigation (n=17). Qualification took place two weeks before the start of the training course. Participants were tested on their physical and cognitive status by the military lead. The participants were informed about the study and the measurements that would be taken prior to providing their written informed consent.

2.2 Equipment

2.2.1 Cognitive Measurement

To assess cognitive performance, three tasks, described below, were performed. Total completion time was about 20 minutes. The tasks were performed on a laptop (MSI U100, Taipei Hsien, Taiwan).

2.2.2.1 Working Memory

Working memory was tested using the N-back task [7,8]. Three levels of difficulty (Zero-back, One-back, Two-back) were included. The participants were presented with a series of capital letters on their laptop screen and were required to press a "1" when the letter presented was on X (for the Zero-back), or when the presented letter was the same as the letter presented *n* stimuli previously (One-back and Two-back). Participants were required to press a "2" in any other situation. Twenty-one letters were randomly presented for one second and separated by an interstimulus interval of one second. Three blocks were presented starting with the 0-back, then the One-back and finally the Two-back. The total duration of the test was five minutes. Reaction time and accuracy were recorded.

2.2.2.2 Logical Reasoning

Reasoning and planning was tested using the Tower of Hanoi test (modified version of http://step.psy.cmu.edu/scripts-plus/ TOHx). Participants were shown a starting and end pattern (Figure 2). Both patterns were shown on screen with information describing the amount of steps needed to transform the starting pattern into the end pattern. Participants were instructed to transform the starting pattern into the end pattern in the amount of moves that was presented, as fast as possible and with a minimum of mistakes. Only one disk could be moved at a time, a larger disk could never be placed on a smaller disk and the disks could only be placed on the pegs. The test consisted of seven patterns that needed to be solved ranging from two-step problems to seven-step problems. On average the time needed to execute the task was five minutes. When a mistake (illegal move) was made, the participant had to start over with the presented pattern.

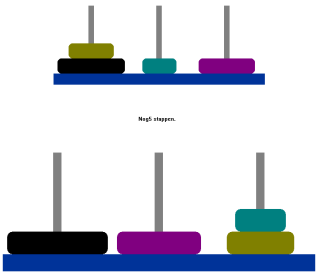

Figure 2: Tower of Hanoi.

The time taken to solve the tasks and the number of illegal moves were recorded.

2.2.2.3 Vigilance

Vigilance was tested using the VigTrack test (Vigilance and Tracking test) [9]. This test consists of a dual-task that is used for measuring vigilance and tracking performance. During the tracking task participants had to steer a blue disk using a joystick within a red circle located in the middle of a computer screen (Figure 3). While performing the tracking task participants were also required to perform a vigilance task. In the middle of the red circle a black square was shown that turned one quarter every second. At random intervals a circle (the target) was presented instead of a square. If the target was presented, participants had to press the fire button on the joystick. The time of the test was set at 5 minutes. The distance from the disk, reaction time, illegal responses, and missed responses were recorded.

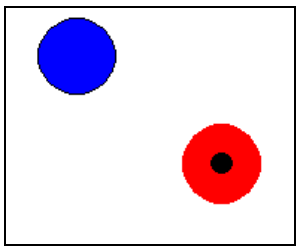

Figure 3: VigTrack test.

2.3 Study Procedure

The Air Mobile Brigade training course started on the 25th of August 2008 and lasted till the 10th of October 2008. The baseline measurement were recorded on August 22nd 2008. During this day participants were informed about the purpose of the measurements, received information about all measurements, got acquainted with the monitoring systems, filled in an extended list of questionnaires, practiced the tasks three times and were free to ask questions.

In the first (25th – 29th August), third (8th – 12th September) and fifth (22nd – 26th September) week of the training course the participants were physically challenged. It was during these weeks that the participants had to perform cognition tasks on five occasions (Figure 4 shows the test set-up); on Monday, Wednesday and Friday morning and in the afternoon on Wednesday and Friday. During the days in which the cognitive testing took place, the physiological parameters of the participants were continuously measured.

Figure 4: Test set-up.

During the remaining training course weeks (week two, four, six and seven), participants were not measured since there was a lack of physical activity in these weeks.

Participants went home over the weekends. On the 5th of October cognitive function was tested and each participant was required to fill in the questionnaires. The series of tests were repeated at the 13th of October, the final testing day, along with an extended set of questionnaires. An overview of the study design is presented in Figure 5a. Figure 5b shows the design of the study during a testing day.

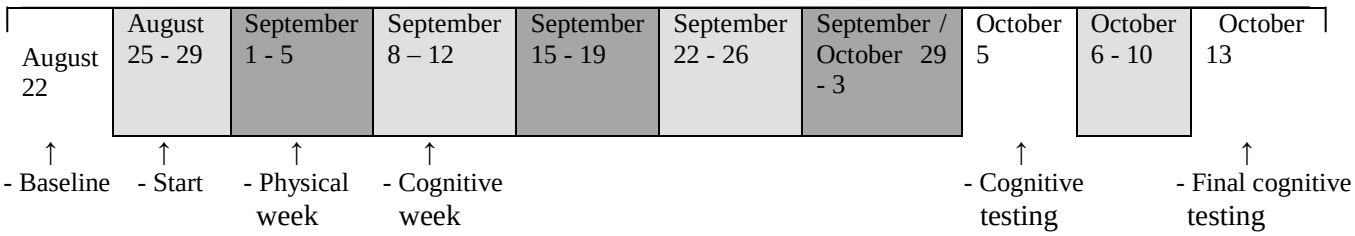

Figure 5a: Overview of the tests during the training course.

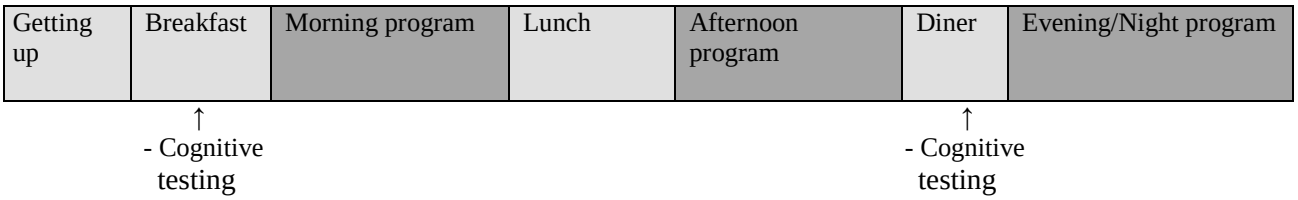

Figure 5b: Overview actions during measurement days (Monday, Wednesday and Friday) in the physical weeks. (On Monday the cognitive testing took place only in the morning).

2.4 Statistical Analysis

A within subjects, two-way (week (3) x test session (5)) repeated measures, ANOVA was used to analyse the data from the participants who completed the training course, using Statistica 7.0 software (Statsoft, Tulsa, USA). When the two-way ANOVA revealed significant interactions a Tukey Honest Significant Difference (HSD) test was used to locate the differences. The level of statistical significance was set at $p = 0.05$.

3.0 RESULTS

During five test sessions participants performed cognitive tasks. The test sessions were:

1 – Monday morning

2 – Wednesday morning

3 – Wednesday afternoon

4 – Friday morning

5 – Friday afternoon

3.1 Working Memory (N-back Task)

The percentages of correct responses of the three levels of the N-Back task (the Zero-Back, the One-Back and the Two-Back) revealed significant interaction effects (Zero-Back: [$F(8,64)=11.03$, $p< 0.01$]; One-

Back: [$F(8,64)=12.06$, $p< 0.01$]; Two-Back: [$F(8,64)=6.68$, $p< 0.01$]). During week 2 the percentage of correct responses was significantly lower when compared to the percentages in week 1 and 3 for all three difficulty levels. Figure 6 shows the results for the Two-Back. Higher difficulty levels of the N-Back led to greater decreases in participant's performance.

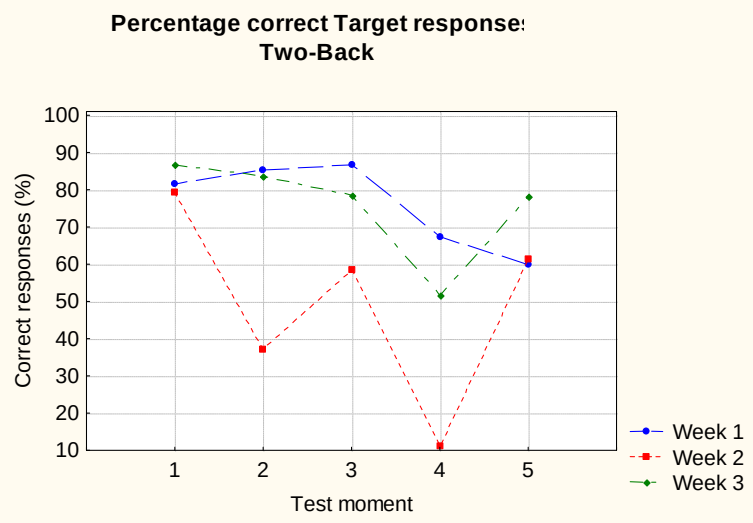

Figure 6: % Correct Target Responses Two-Back.

In the Two-Back condition the percentage of correct target responses were significantly ($p< 0.01$) lower on Wednesday- and Friday morning in week 2. On Friday morning in week 3, the percentages of correct responses were significantly lower compared to the other test moments that week ($p< 0.05$).

Significant interactions effect were found for the reaction times during the Two-Back [$F(8,64)=2.16$, $p< 0.05$]. The Friday morning test resulted in significantly lower reaction times compared with the tests on Wednesday morning and Friday afternoon ($p< 0.05$) (Figure 7).

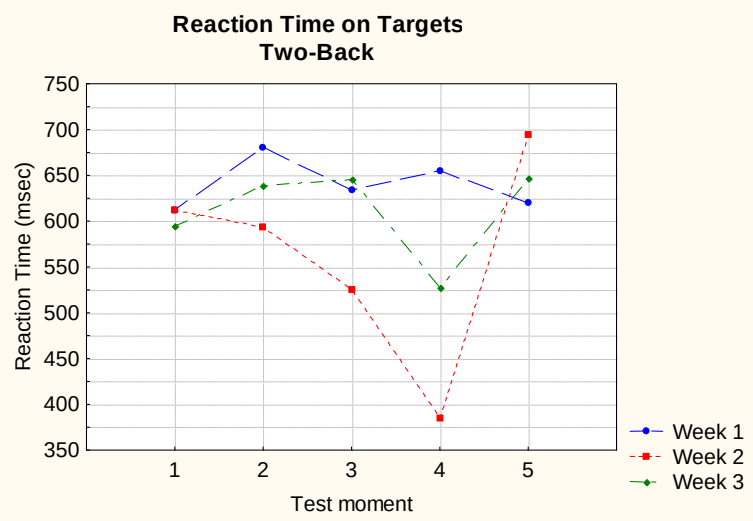

Figure 7: Reaction Time Target Two-Back.

3.2 Logical Reasoning (Tower of Hanoi)

Logical reasoning showed significant interaction effects in completion time and initiation time (mean completion time: [$F(8,64)=11.08$, $p< 0.01$]; mean initiation time: [$F(8,64)=6.69$, $p< 0.01$]).

The completion time in week 2 differed significantly from the completion time in week 1 and 3 ($p< 0.01$) while the initiation time differed significantly between all weeks ($p< 0.05$).

On Wednesday and Friday mornings participants needed significantly longer completion and initiation times ($p< 0.01$) compared with all other test sessions in week 1, 2 and 3.

3.3 Alertness/Vigilance (VigTrack)

Tracking performance (RMS) showed significant interaction effects [$F(8,64)=9.93$, $p< 0.01$]. During week 2 tracking performance was significantly worse compared to week 1 and 3 ($p< 0.01$), (Figure 8). On Friday afternoon in week 1, participants had significantly higher tracking error scores compared to test sessions 1 to 3 of that same week ($p< 0.01$).

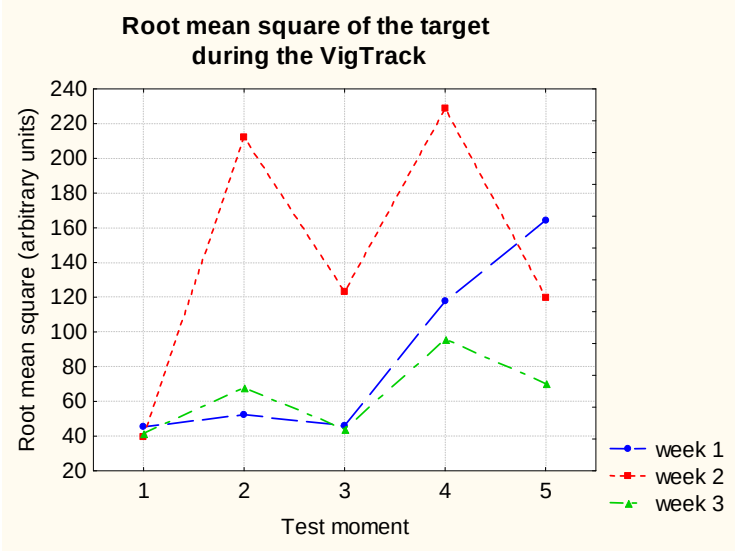

Figure 8: Root mean square of the target during the VigTrack.

Tracking performance results during week 2 were variable. The performance profile of the second week differed significantly from the profile seen in week 1 and 3. In particular, during the test sessions on Wednesday- and Friday morning tracking performance was poorer. These two test sessions in week 2 had significant different results compared to the same test sessions in week 1 and 3 ($p< 0.01$). Wednesday afternoon in week 2 resulted also in significant worse tracking performance compared to the same test session in week 1 and 3 ($p< 0.05$).

Except for reaction times of the first test sessions, for each week, participants had significant differences for the vigilance sub-task. Reaction times showed significant interaction effects [$F(8,64)=6.47$, $p< 0.01$] (Figure 9). Impaired reaction times were found during the second week compared to the other weeks ($p< 0.01$).

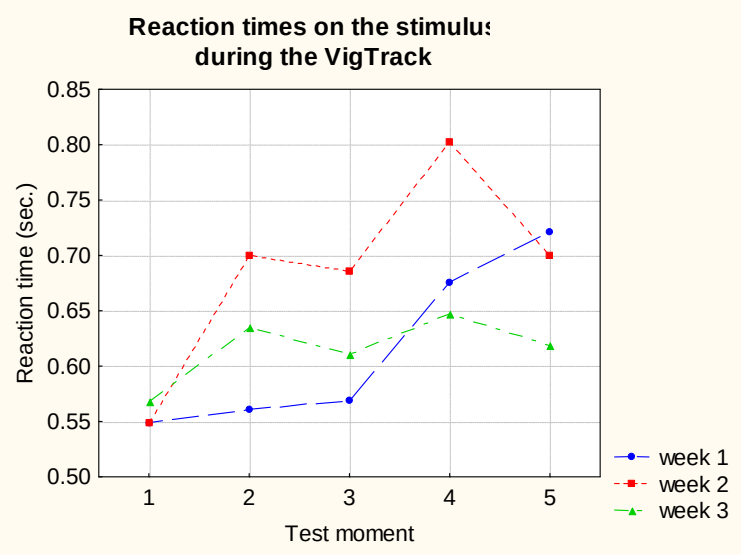

Figure 9: Reaction times on the stimulus during the VigTrack.

Reaction times during week 1 were significantly slower during the Friday morning and afternoon sessions compared with the other sessions that week ($p < 0.01$). The reaction time was significantly faster during the Monday morning session in week 2 compared with the other sessions that week. During the Friday morning session of week 2, reaction times were significantly slower compared to all other sessions that week. No session effect was found in week 3.

A significant interaction effect was found for the percentage missed targets [$F(8,64)=9.15$, $p < 0.01$] (Figure 10). The percentage missed targets was significantly higher during week 2 compared to week 1 and 3 ($p < 0.01$). On Friday afternoon in week 1, a significantly higher percentage of missed stimuli was found compared to the first three test moments that week ($p < 0.01$). On Monday morning in week 2 a significantly lower percentage of missed stimuli was found compared with the other test sessions that week ($p < 0.01$). In particular, the sessions on Wednesday and Friday morning in week 2 showed high percentages of missed stimuli (43 and 58% respectively). Test sessions 2, 3 and 4 in week 2 revealed significant higher percentages of missed stimuli than the same test sessions in week 1 and 3 ($p < 0.01$).

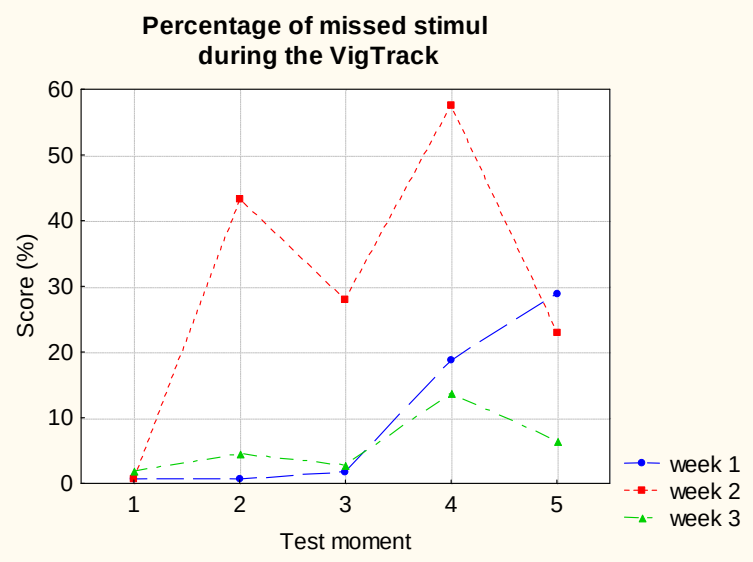

Figure 10: Percentage of missed stimuli during the VigTrack.

4.0 DISCUSSION

This investigation was performed to gain more insight into the effects of prolonged physical and mental strains in combination with variables such as sleep loss during a sustained training setting. Three different cognitive tasks were used to measure cognitive performance and all tasks showed identical patterns in test results. Cognitive performance differed significantly between and within weeks. During week 1 and 3 an ascending degradation of cognitive performance was found over the weeks while the cognitive performance in week 2 showed an irregular pattern over the week with the cognitive performance being the worst on Wednesday- and Friday morning.

The most variance in the test results was observed during the most difficult N-Back test (the Two-Back) between and within weeks. The Zero-Back and One-Back are easy tasks to execute compared to the Two-Back. Other studies [10] have shown that very complex memory tasks are not sensitive enough when measuring cognitive performance. The Two-Back test seems to be a task that tests working memory without being overly difficult. Thus making the task a sensitive measure of cognitive changes.

Differences between the Tower of Hanoi scores were minimal. The test results were only different on the Wednesday and Friday morning in week 2. The other scores showed little variation. Comparing the Two-Back score variation with the Tower of Hanoi score variation, the Tower of Hanoi seems to be a less sensitive task to measure cognitive performance in soldiers during sustained operations. This might be due to the fact that the Tower of Hanoi measures logical reasoning instead of working memory and that the Tower of Hanoi task is also a more complex task compared to the other tasks used. Disks are moved by selecting them with a mouse click and then clicking the peg where the disk has to be moved to. No disk or peg is selected when clicking too far from the disk or peg. Not directly selecting the disk or peg affects completion time. These types of incidents happen easily even with well rested participants. Also, wrong steps might be taken when starting the tasks too fast without taking enough time to over think the right steps needed to solve the puzzle. This decrease in concentration can overshadow the effects of a diminished logical reasoning.

The VigTrack showed to be sensitive to cognitive changes. Results of both the tracking and vigilance sub-tasks (the percentage missed stimuli and the reaction times) show an almost identical pattern; when tracking performance decreased, more stimuli were missed. This phenomenon can be explained by the fact

that when the disk is far away from the middle of the screen (where the target is being displayed), it is difficult to keep an eye on the disk in order to steer it to the middle and, at the same time, to keep an eye on the target. Participants need a split vision in order to do that. The use of split vision needs concentration which is hard to do when someone is exerted. Therefore, performance decreases.

The first and third measurement weeks were mainly physical weeks in which soldiers were pushed to their physical limits. Soldier's physically exhaustion and lack of sleep increased over the two weeks resulting in a worsening of their cognitive performance. Cognitive performance during week three was comparable to week 1. The results were slightly better during week 3 which might be due to the differences in physical performance. Soldiers had to deal with less strenuous physical performance in week 3 compared to the strains during the first week. This was due to the training focus of the week. During week 1 individual performance was important while group processes were the focus of week 3.

During the second week soldiers were challenged physically in combination with high mental strains. Results show that cognitive performance during the second week was more severely affected compared to the other two weeks. This might be the result of the combination of physical and mental strain. The decreased cognitive performance of the soldiers recovered quickly. Despite the decrease in cognitive performance, seen on Wednesday and Friday morning in week 2, no performance decrement was evident during the following test session in the afternoon the same day. According to these results it is very likely that cognitive performance degradation occurs more easily and more severely when soldiers are exposed to high physical and cognitive strains. At the same time, soldiers are very well capable of restoring their cognitive performance in a short period of time.

Soldiers started all three weeks with test results that were on the same level. Obviously, the previous week and/or the weekend offered enough time to recover cognitively.

4.1 Limitations of the Study

Participants were very tired as a result of the very demanding training course. On some occasions participants fell asleep while performing the cognitive tasks. As soon as participants fell asleep, they were awakened by one of the experimenters. This was done to make sure the participants completed all the testing within the 30 minutes of test time. Not waking the participants would have led to data loss.

5.0 CONCLUSIONS/RECOMMENDATIONS

Cognitive tasks give insight in the cognitive performance of soldiers during a sustained training course. The measurements performed during the training course reveal that when soldiers are physically and/or mentally challenged, cognitive performance is negatively affected. Physical strain by itself influences cognitive performance while physical strains in combination with psychological strains affect cognitive performance even more. Although significant drops in cognitive performance occurred, soldiers are capable of restoring their cognitive performance in a short time period.

It remains unclear what has caused the major drops in cognitive performance and what facilitated the increase in performance after the significant performance degradations. It would be interesting to investigate to what extent psychological strains, physical strains and the combination of both influences cognitive performance. Since our measurements took place in the field, the cause of the drops might be a combination of physical and mental strains, as well as lack of nutrition, lack of water intake, lack of sleep etc. Controlled lab studies, should give more insight into the effects of several factors on cognitive performance.

6.0 REFERENCES

[1] Lamond, N., Jay, S. M., Dorrian, J., Ferguson, S. A., Jones, C. & Dawson, D. (2007). *The dynamics of neurobehavioral recovery following sleep loss.* Journal of Sleep Research, 16, 33-41.

[2] Friedl, K. E., Mays, M. Z., Kramer, T. R. & Shippee, R. L. (1995). *Acute recovery of physiological and cognitive function in U.S. army ranger students in a multistressor field environment.* Paper presented at the RTO HFM Workshop on " The effect of prolonged military activities in man. Physiological and biochemical changes. Possible means of rapid recuperation", Oslo, Norway, 3-5 April 1995 and published in RTO MP-042.

[3] Nindl, B. C., Leone, C. D., Tharion, W. J., Johnson, R. F., Castellani, J. W., Patton, J. F. & Montain, S. J. (2002). *Physical performance responses during 72 h of military operational stress.* Medicine and Science in Sports and Exercise, 34 (11), 1814-1822.

[4] Stroud, M. A. (1995). *The biochemical and physiological effects of 95 days endurance exercise in negative energy balance.* Paper presented at the RTO HFM Workshop on " The effect of prolonged military activities in man. Physiological and biochemical changes. Possible means of rapid recuperation", Oslo, Norway, 3-5 April 1995 and published in RTO MP-042.

[5] Hogervorst, E., Riedel, W., Jeukendrup, A., Jolles, J. (1996). *Cognitive performance after strenuous physical exercise*. Perceptual & Motor Skills, 83 (2), 479-88.

[6] Fery Y.A., Ferry A., Vom Hofe A., Rieu M. (1997). *Effect of physical exhaustion on cognitive functioning.* Perceptual & Motor Skills, 84 (1), 291-8.

[7] Gevins, A. & Cutillo, B. (1993). *Spatiotemporal dynamics of component processes in human working memory.* Electroencephalography and Clinical Neurophysiology, 87 (3), 128-143.

[8] Owen, A.M., McMillan, K.M., Laird, A.R. & Bullmore, E. (2005). *N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies*. Human Brain Mapping, 25 (1), 46-59.

[9] Valk, P.J., Simons, R.M, Struyvenberg, P.A., Kruit, H. & Van Berge Henegouwen, M.T. (1997). *Effects of a single dose of loratadine on flying ability under conditions of simulated cabin pressure.* American Journal of Phinology, 11 (1), 27-33.

[10] Harris, W. C., Hancock, P. A. & Harris, S. C. (2005). *Information processing changes following extended stress.* Military Psychology, 17 (2), 115 – 128.